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SUGGESTIONS FOR THE SAFE OPERATION OF GASOLINE ENGINES IN MINES

BY

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SUGGESTIONS FOR THE SAFE OPERATION OF GASOLINE ENGINES IN MINES.

By R. H. KUDLICH and EDWIN HIGGINS.

INTRODUCTION.

Gasoline engines, on account of their small cost and the comparative ease with which they may be transported to remote places, appeal to contractors and to operators of small mines. Operators of larger mines also favor their use for haulage. These engines are used for pumping or haulage, and in small metal mines are frequently used for driving hoists. For sinking a winze or shaft from the end of a long adit, a gasoline hoist may be most desirable. At such places ventilation is usually poor and a gasoline engine used there menaces both the health and the safety of miners unless it is properly handled.

Prospectors frequently purchase second-hand machinery that is defective. Gasoline connections and parts of the engine may be leaky. At small mines it is seldom that a specially trained man is kept in charge of a gasoline engine; on the contrary, men of little experience frequently run it. Under such conditions gasoline is often handled carelessly and safety precautions are neglected. The mining laws of some States forbid the use of gasoline or any petroleum product for generating power inside a mine. The laws of other States allow its use in engines, provided certain precautions are taken to guard against the attending hazards. But in all mining States there are many small or remote mines that must necessarily be neglected to some extent by the mine inspectors whose time is largely taken up with the inspection of larger mines.

A previous bulletin^a of the Bureau of Mines contains a discussion of the conditions that affect the volume and character of the exhaust gases of gasoline locomotives and points out the dangers attending the use of such locomotives. The present paper deals especially with the precautions that should be taken to prevent gasoline locomotives causing mine fires or explosions or pollution of the mine air.

^a Hood, O. P., and Kudlich, R. H., Gasoline mine locomotives in relation to safety and health, with a chapter on methods of analyzing exhaust gases: Bull. 74, Bureau of Mines. 1915. 83 pp.

CHIEF DANGERS FROM GASOLINE ENGINES IN METAL MINES.

Under ordinary operating conditions in metal mines, the chief dangers in the use of gasoline engines are as follows:

1. Fires resulting from leaky containers or careless handling of gasoline.
2. Explosions caused by the ignition of an accumulation of gasoline vapor.
3. Poisonous gases in the engine exhaust.

The first two affect the health and the safety of the miner as well as the safety of the mine, and the last affects the health, comfort, and safety of the miner.

Everybody knows that gasoline burns, and that timbers or other material saturated with gasoline readily take fire. In order to guard against fires underground, gasoline engines should not be installed in timbered places, and as little timber as possible should be used in the engine foundation. The foundation material, as far as feasible, should be covered with broken rock or cement. If a gasoline engine must be used in a timbered place, protection should be afforded by covering the timber in the vicinity of the engine with asbestos board. Great care should be used in handling the gasoline in order to prevent the saturation of any woodwork or the floor. Gasoline should not be left around the engine in open containers, and if a priming can is used it should be closed like an oil can and kept in a place where it will not be overturned or subject to damage.

EXPLOSIONS CAUSED BY GASOLINE VAPORS.

Danger from explosion is closely allied to danger from fire. Not only is gasoline in the liquid state very inflammable, but if exposed to the air it vaporizes readily at ordinary temperatures. Pure gasoline vapor entering a flame will burn quietly if surrounded with air, but if it is mixed with the proper proportion of air and then ignited it will explode violently if in the least confined.

Under the conditions usual in mines, air containing 1.4 to 6.4 per cent of gasoline vapor will explode in the presence of an open flame, such as that of a candle, carbide lamp, or match. It is important to note that such a small proportion of gasoline vapor will form an explosive mixture with air. If any quantity of gasoline between one-half gallon and 2 gallons be spilled or leaks from a container and then vaporizes and mixes thoroughly with the air in a room 7 feet high by 9 feet wide by 15 feet long, it will form an explosive mixture throughout the room. Such conditions of thorough mixing are not common, the gasoline vapor being mixed with the air in different proportions at different points. Yet at any particular point the pro-

portions may be such as to cause a violent explosion if the mixture is ignited by an open light, a cigarette, or an electric spark.^a

BEHAVIOR OF GASOLINE VAPOR.

Gasoline vapor is heavier than air and, unless disturbed by air currents, will flow along the ground like a stream of water. In this way a train may be set from the source of vapor to a point at some distance where it may be ignited, the flame flashing back and firing the gasoline from which the vapor comes. Places where gasoline must be drawn or poured from one vessel into another should be amply ventilated so that the vapor will be diluted and swept away as soon as it is formed. Gasoline should never be so handled in the presence of open lights.

CHARACTER OF EXHAUST GASES FROM GASOLINE ENGINE.

It should be borne in mind that the gases from a gasoline engine are poisonous unless greatly diluted with moving fresh air. A knowledge of this fact is as necessary as of the fact that explosives are dangerous. However, these gases, when properly diluted, become harmless. The exhaust from a gasoline engine is a mixture of gases, some harmless and some dangerous. The most dangerous is carbon monoxide. Carbon monoxide is the product of burning carbon without enough air. It is the most dangerous gas in what the coal miner knows as "after damp." One part of carbon monoxide in 1,000 parts of air may be breathed for short infrequent intervals of time without discomfort or danger, but one part of this gas in 500 parts of air may cause severe headache after it is breathed a short time. A little more carbon monoxide may cause unconsciousness and finally death.^b

As a rule, the first symptoms of carbon monoxide poisoning are a headache and weakness in the legs. Occasionally, however, these symptoms are not noticed, and the victim loses consciousness suddenly and without warning.

PROPORTION OF CARBON MONOXIDE IN EXHAUST GASES.

The amount of carbon monoxide in the exhaust of a gasoline engine varies with the size of the engine and the adjustments and methods of operation. If the engine and its carburetor, or mixing valve, are in perfect adjustment, only enough gasoline will be burned with a proper amount of air to produce the power needed, and little, if any, carbon monoxide will be given off. However, if all adjust-

^a See Burrell, G. A., Hazards in handling gasoline: Technical Paper 127, Bureau of Mines, 1915, p. 10.

^b Burrell, G. A., Selbert, F. M., and Robertson, I. W., Relative effects of carbon monoxide on small animals: Tech. Paper 62, Bureau of Mines, 1914, p. 21.

ments are not perfect, too much gasoline is burned and the exhaust contains considerable carbon monoxide. This condition is common in engines as adjusted and used around mines. The presence of a dangerous amount of carbon monoxide in the exhaust, or in the mine air, can be detected only by special tests. The gas is odorless and colorless and will not produce any effect on the flame of a safety lamp or candle unless it is present in such large amounts as would cause almost immediate death to anyone breathing the air containing it.^a

Therefore, whenever a gasoline engine is used in a mine, or in any closed place, it must be assumed that at some time the greatest possible amount of carbon monoxide will be generated, and enough air must be circulating around the engine to dilute this so as to make it harmless. Ventilation must go with a gasoline engine to make its operation safe. It has been found by experiment that a gasoline engine can generate as much as 0.45 cubic foot of carbon monoxide per rated horsepower per minute.^b

The amount of carbon monoxide generated by a few of the common sizes of gasoline engines under bad operating conditions, and the least amount of air required to render the maximum quantity harmless are given in Table 1 following.

TABLE 1.—*Maximum amounts of carbon monoxide that different sizes of single-cylinder, four-cycle gasoline engines produce under conditions of improper carburetor adjustment.*

Rated horsepower.	Size of engine cylinder.	Speed.	Maximum probable quantity of carbon monoxide produced with poor carburetor adjustment. ^a	Minimum quantity of air required to dilute exhaust below dangerous limit. ^a
	<i>Inches.</i>	<i>R. p. m.</i>	<i>Cu. ft. per min.</i>	<i>Cu. ft. per min.</i>
1½.....	3½ by 5	550	0.76	760
2½.....	4 by 6	450	1.13	1,130
3.....	5 by 7½	425	2.09	1,090
7.....	5½ by 9	375	2.92	2,920
9.....	6½ by 11	325	3.95	3,950
12.....	7½ by 12	300	5.30	5,300

^a At 60° F., with barometer at 30 inches.

The quantity of air required for engines with more than one cylinder can be obtained by multiplying the number of cylinders by the quantity of air required by a one-cylinder engine with the same size of cylinder. Two-cycle engines will require twice the amount of air required by four-cycle engines with the same size of cylinder.

^a Burrell, G. A., and Selbert, F. M., Gases found in coal mines: Miners' Circular 14, Bureau of Mines, 1914, p. 13.

^b Hood, O. P., and Kudlich, R. H., Gasoline mine locomotives in relation to safety and health: Bull. 74, Bureau of Mines, 1915, p. 7.

DISPOSAL OF EXHAUST GASES.

Unless the necessary amount of air, as indicated by the table, is passing the engine the disposal of the exhaust gas becomes of great importance. In many metal mines, especially small mines and prospects, ventilation is not given much consideration. In most metal mines dependence is placed solely on natural ventilation. It is not necessary to explain that such ventilation is uncertain. Changes in the direction of the wind, or in atmospheric conditions, may quickly reverse the direction in which the air is traveling. Frequently the air current is feeble or there is no movement of air whatever.

Therefore, in planning for the disposal of the exhaust gases from gasoline engines in mines safety may generally be guaranteed only by carrying the exhaust to the surface. If, however, an airway in some part of the mine where men are never required to travel carries a strong return current, it might be safe to discharge the exhaust therein. Great care should be observed in keeping the exhaust pipe line in repair. If that part of the mine in which the engine is working is ventilated by an exhaust fan, it would be safe to carry the engine exhaust into the return air duct through which the fan draws the air. The gasoline engine is a constant menace to the health of the men working in the mine unless one of these methods is followed.

To turn the exhaust into the sump or into running water is useless, as carbon monoxide is practically insoluble in water. It will bubble up through water without being changed in any way except that the smoke and the odor of accompanying gases may be removed, the poisonous quality of the gas remaining unchanged. Thus the possible warning of the presence of carbon monoxide by the odor of accompanying gases will be removed if the exhaust is turned under water.

Even if a sufficient volume of air is passing the engine the exhaust pipe should be placed so that the engineer will not be exposed to the undiluted exhaust gases. As the exhaust leaves the pipe it may contain carbon monoxide enough to render unconscious anyone breathing a few breaths of it. In one case reported to the Bureau of Mines a man was overcome in this manner while working directly in front of the exhaust pipe of a gasoline locomotive which was idling. The amount of air passing through the entry was several times the amount required to properly dilute the greatest amount of carbon monoxide that the engine could produce, but near the exhaust pipe the gases had not become diluted enough to be safe.

EFFECT OF GASOLINE FUMES.

The health of men working around gasoline may be affected also by inhaling the vapor or fumes given off. If a large surface of

gasoline be exposed to the air in a confined space, the air will become heavily charged with the vapor. Anyone breathing such an atmosphere for some time is liable to become intoxicated. Air so charged is frequently present in some oil refineries, gasoline storage depots, and tank repair shops where men are obliged to go into tanks that have contained gasoline to clean or repair them, and in cleaning establishments where gasoline or naphtha is used in rooms that are kept tightly closed and are poorly ventilated.

Around mines probably the only time a workman could be similarly affected by gasoline vapor would be when a quantity of gasoline had been spilled in a closed room. If a proper system of handling gasoline inside the mine is followed, such an accident should be impossible. It might happen on the surface in a tightly closed room where gasoline leaked from a tank or faucet. By thoroughly ventilating such places, or by storing quantities of gasoline in the open, this danger can be entirely avoided.

STORAGE OF GASOLINE.

More gasoline than is required for one day's work should never be stored in a mine. The supply should be kept outside, preferably in a tank buried in the ground, and the gasoline should be pumped from it as required. If such a tank can not be provided, the gasoline should be kept in a well-ventilated room or house. The proper way to handle gasoline from storage is with a pump so arranged that any overflow or leakage while cans are being filled is returned to the tank and not allowed to evaporate. If a pump is not provided, storage barrels or tanks must be so placed that leakage from an imperfect or improperly closed faucet or the breakage of a pipe or connection will not allow gasoline to collect in an inclosed space, as a room, or allow the vapors to flow down to a possible source of ignition such as a boiler or forge fire. In other words, large quantities of gasoline should be stored on the surface, either above ground in an open or thoroughly ventilated place, or preferably in underground tanks, from which it is pumped. Open lights or lighted pipes or cigarettes must never be carried into a room where gasoline is stored or is used in open vessels. If it is absolutely necessary to have artificial light in such places only miners' safety lamps or approved electric lights should be used.^a All electric lamps should be protected with substantial wire guards, and all switches, fuses, etc., should be placed outside of the room to prevent sparks or flashes igniting any gasoline vapor that may be present.

^a Clark, H. H., Electric lights for use about gas or oil wells: Tech. Paper 79, Bureau of Mines, 1914, 8 pp.

If by accident gasoline be spilled, naked lights should never be brought anywhere near it until it has entirely evaporated and ample time for the complete sweeping away of the vapors has elapsed. If gasoline is spilled in a closed place, all doors, etc., should be opened to allow the air to circulate through the place as freely as possible.

HANDLING OF GASOLINE FOR A MINE ENGINE.

In the mine especial care must be taken in handling gasoline at the engine. Most engines as purchased have fixed tanks into which the gasoline must be poured from the container in which it is brought into the mine. This arrangement is bad. More accidents with gasoline engines have resulted from a man carrying a naked light or smoking while filling such fixed tanks than from any other cause.

In drawing gasoline or pouring it from one container into another static electricity may be generated. It has been shown by experiments that unless the containers are grounded and are in electrical connection with each other, the accumulated electricity may discharge by a spark sufficiently strong to ignite the gasoline vapors.^a The use of portable tanks will entirely eliminate this danger within the mine. At the filling station the tanks, etc., should be connected electrically in order to prevent such accumulations. Cans with handles of wood or any other insulating material should never be used for handling gasoline. If a hose with a metal nozzle is used, a bare copper wire inside the hose and soldered to the nozzle and to the tank connection will complete the circuit. If a can and a funnel are used, they may be attached to the tank with light copper or brass chain.

By far the safest method of handling the gasoline for an underground engine is in a portable fuel tank. After the tank is filled on the surface, and all openings are closed, it is carried into the mine and connected directly to the fuel line of the engine to serve as the fuel supply tank. With this system it is not necessary to pour the gasoline from one vessel into another in the mine. Thus the greatest danger of fire is entirely eliminated.

^a The ignition of gasoline by electricity: *Travelers Standard*, vol. 4, May, 1916, p. 86; Gasoline fires caused by sparks when filling tanks: *Chase, Herbert, Motor Travel*, vol. 8, June, 1916, p. 37.

PORTABLE TANK FOR GASOLINE ENGINE.

A portable tank is shown in figure 1. It consists of a cylindrical can, with the filling opening and the feed-pipe connection in one end

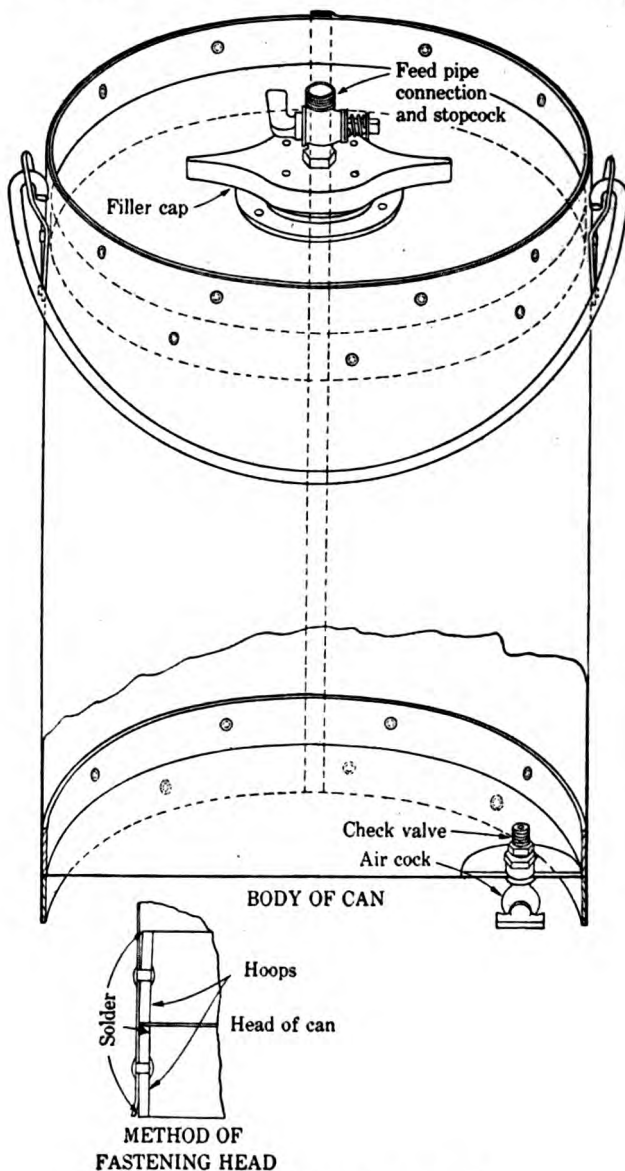


FIGURE 1.—Portable gasoline tank.

and an air cock, to admit air as the gasoline is drawn out, in the other end. When the can is being filled and transported the air

cock is at the bottom. When the tank is connected to the engine it is inverted from the carrying position, and the head bearing the air cock becomes the top of the can.

Such a tank can be made by any tinsmith or worker of light sheet metals. It should be made of the heaviest galvanized iron he can conveniently work, say, No. 20 or No. 22 gage. The fittings may be bought of a hardware or automobile supply shop.

In the top head of the tank is a gasoline-tank filling cap and flange, a stopcock of suitable size for the feed-pipe line of the engine being tapped into the cap. The free end of the stopcock has a union for connecting it to the feed line. In the bottom head is a $\frac{1}{8}$ -inch pet cock tapped into a small brass flange inside of the tank. A ball check valve, set to admit air into the tank but not to allow gasoline

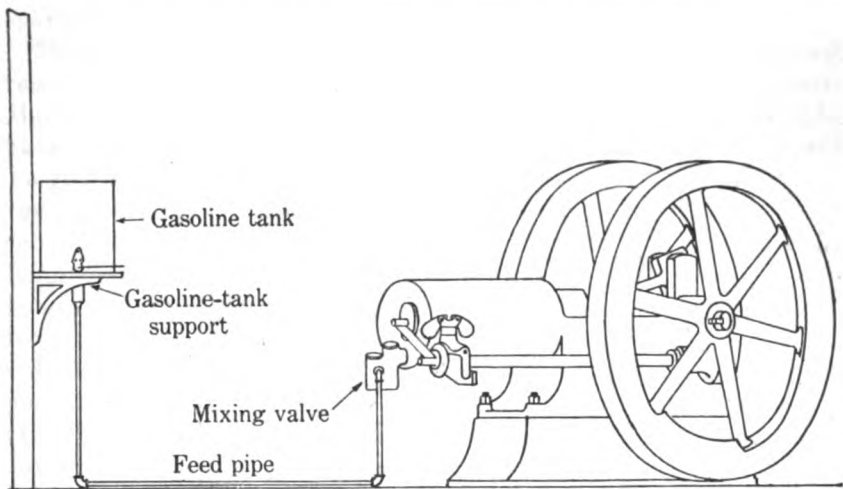


FIGURE 2.—Arrangement of gasoline engine, portable tank, and feed pipe.

to escape, is screwed on the end of the pet-cock stem projecting within the tank. This cock is placed near the edge of the can to diminish the danger of its being injured if the can is set on an irregular floor. The flanges are riveted and soldered to the heads, and the screw connections are soldered to prevent their working loose.

The edges of the galvanized iron forming the cylindrical body of the can are joined with an ordinary hook joint soldered inside and outside. The heads are both flat and are let into the body enough to insure clearance for the air cock on one head or the filler cap on the other when the can is set on a moderately irregular floor.

As shown in figure 1, the heads are held between hoops riveted and soldered to the inside of the shell. A space of about $\frac{1}{16}$ inch, left between the outside faces of the heads and the outside hoops, is

filled with solder to make the joints tight. To prevent possible leakage between the steel and the hoops, the edges of the shell are slightly separated from the hoops and the space thus formed is filled with solder. All rivet heads must be soldered.

Such a tank if carefully made and thoroughly soldered will stand considerable rough handling without developing leaks.

To use such a tank on an engine the gasoline feed pipe is permanently disconnected from the original fuel tank of the engine and is then extended to a suitable point a short distance from the engine and at about the same elevation as the outlet of the original fuel tank (see fig. 2). To the free end of the pipe is fitted the other half of the union on the stopcock of the portable tank. A suitable support built to receive the gasoline tank is so placed that the part of the

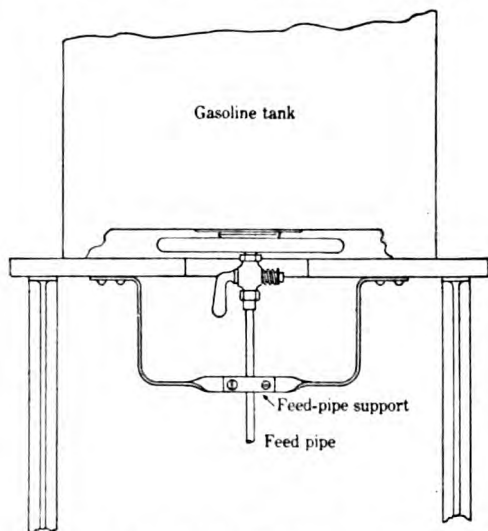


FIGURE 3.—Support for portable gasoline tank.

union on the stopcock may readily be connected with the part on the end of the feed line (see fig. 3).

In service, this gasoline tank may be filled on the surface by daylight, carried into the mine, and connected to the engine, without at any time exposing the gasoline to possible ignition.

The tank as returned to the filling station should have both the pet cock and the stopcock tightly closed. It is then to be filled and the filler cap screwed down tightly.

At the engine the can is inverted so that the filler opening and the stopcock are at the bottom, and is placed on its support, and the feed line is connected by means of the union. Then the stopcocks and the air cock are opened and the gasoline is delivered to the carburetor or mixing valve without having been previously exposed.

When the tank is empty of liquid gasoline, in order to prevent the escape of the highly inflammable or explosive gasoline vapors with which the can is filled both cocks should be closed before the tank is disconnected.

DANGERS FROM EMPTY GASOLINE TANKS AND GASOLINE-VAPOR ACCUMULATIONS.

These seemingly empty gasoline cans or tanks are probably more dangerous than those filled with gasoline. Usually the can will not be entirely emptied but will contain a little liquid gasoline that did not run out. This gasoline will vaporize, the vapor will mix with the air in the can, and the mixture may easily be explosive. When the can is being filled this mixture of gasoline vapor and air is forced out by the gasoline and may explode if it is ignited by a flame or spark near the opening.

Many engines are built with cavities or inclosed spaces in the crank case, base, or some other part; these may be full of gasoline vapors. Many men, when inspecting or making repairs with an open light, have been severely burned when these vapors have been ignited. To guard against such accidents all cavities should be blown out with compressed air or steam. If neither of these is available the cover should be removed, the vapors should be fanned out, and a lighted lamp or candle attached to a long stick should be passed around inside the cavities to burn out any vapors that may remain before the workman puts his hands or face near them.

Unless an ample current of air at considerable velocity is passing, gasoline should not be used to clean oil and dirt off of an engine or other machinery. Even if there is sufficient air to sweep away the vapors as soon as they are given off, open lights should always be kept at a safe distance and on the intake side so that the vapor can not be carried to the light.

EXTINGUISHING GASOLINE FIRES.

If by any accident gasoline is ignited, never use water to extinguish the fire. A large quantity of water thrown on the fire with considerable force may possibly be effective, but is much more likely to spread the fire. Burning gasoline floats on water and thus spreads the blaze. The best method is to use a reliable chemical fire extinguisher. If none is at hand, the fire should be smothered with sand, or sawdust, or heavy cloths. Wherever gasoline is used or stored it is always well to have buckets of sand on hand for emergencies.

Gasoline carelessly or improperly used is a constant menace to the health and safety of everybody in the mine. It is to be classed with

explosives. If, however, precautions as outlined in this report are taken and due care is exercised in using gasoline, its use as engine fuel offers little, if any, more danger than that of other forms of mechanical power.

SUMMARY OF PRECAUTIONS IN USING GASOLINE ENGINES AND HANDLING GASOLINE.

In order to minimize the risk of fires, observe these precautions:

1. Keep open lights away from all gasoline cans or tanks, feed pipes, and engines.

2. Use only closed cans or tanks for carrying gasoline into the mine.

3. Use only a closed can, like an oil can, for priming with gasoline, and keep the can where it can not be knocked over.

4. Never store more than five gallons of gasoline or as much more as is required for one day's work in the mine.

5. Do not let oily waste or rags lie in the engine room. Put them in a metal pail. Use sand to absorb oil drippings.

6. Never use water to extinguish a gasoline fire. Always use a chemical fire extinguisher or smother the fire with sand. Keep a supply of sand in the engine room and the storage room.

7. Use as little wood as possible for fittings in the engine room. Where possible cover wooden posts, etc., with asbestos board.

To minimize the danger of explosions:

1. Have the engine room and the storeroom well ventilated.

2. Never let gasoline stand in open cans or tanks.

3. Do not pour gasoline from one container into another near open lights.

4. Do not spill gasoline.

5. Do not use gasoline for cleaning in a closed room.

6. Unless all the openings of empty cans or barrels are closed, always store them with the openings down so that the vapors may escape.

To minimize the danger from the exhaust gases of a gasoline engine:

1. Set the carburetor, or mixing valve, to give as lean a mixture as will run the engine.

2. Pipe the exhaust gases out of the engine room.

3. Do not work or even stand near the end of the exhaust pipe when the engine is running.

4. Do not try to purify the exhaust by turning it under water.

5. Unless the ventilation in the place where the engine is used is ample and positive, pipe the exhaust gases to some point where there is such ventilation, or pipe them to the surface.

PUBLICATIONS ON PETROLEUM TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable only from the Superintendent of Documents, Government Printing Office, on payment of the price of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

BULLETIN 74. Gasoline mine locomotives in relation to safety and health, by O. P. Hood and R. H. Kudlich. 1915. 83 pp., 3 pls., 27 figs.

BULLETIN 88. The condensation of gasoline from natural gas, by G. A. Burrell, F. M. Seibert, and G. G. Oberfell. 1915. 106 pp., 6 pls., 18 figs.

BULLETIN 125. The analytical distillation of petroleum, by W. F. Rittman and E. W. Dean. 1916. 79 pp., 1 pl., 16 figs.

BULLETIN 134. The use of mud-laden fluid in oil and gas wells, by J. O. Lewis and W. F. McMurray. 1916. 86 pp., 3 pls., 18 figs.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells, as practiced in California, by Ralph Arnold and V. R. Garfias. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 37. Heavy oil as fuel for internal-combustion engines, by I. C. Allen. 1913. 36 pp.

TECHNICAL PAPER 38. Wastes in the production and utilization of natural gas, and methods for their prevention, by Ralph Arnold and F. G. Clapp. 1913. 29 pp.

TECHNICAL PAPER 42. The prevention of waste of oil and gas from flowing wells in California, with a discussion of special methods used by J. A. Pollard, by Ralph Arnold and V. R. Garfias. 1913. 15 pp., 2 pls., 4 figs.

TECHNICAL PAPER 45. Waste of oil and gas in the Mid-Continent fields, by R. S. Blatchley. 1914. 54 pp., 2 pls., 15 figs.

TECHNICAL PAPER 49. The flash point of oils, methods and apparatus for its determination, by I. C. Allen and A. S. Crossfield. 1913. 31 pp., 2 figs.

TECHNICAL PAPER 57. A preliminary report on the utilization of petroleum and natural gas in Wyoming, by W. R. Calvert, with a discussion of the suitability of natural gas for making gasoline, by G. A. Burrell. 1913. 23 pp.

TECHNICAL PAPER 66. Mud-laden fluid applied to well drilling, by J. A. Pollard and A. G. Heggem. 1914. 21 pp., 12 figs.

TECHNICAL PAPER 68. Drilling wells in Oklahoma by the mud-laden fluid method, by A. G. Heggem and J. A. Pollard. 1914. 27 pp., 5 figs.

TECHNICAL PAPER 70. Methods of oil recovery in California, by Ralph Arnold and V. R. Garfias. 1914. 57 pp., 7 figs.

TECHNICAL PAPER 72. Problems of the petroleum industry, results of conferences at Pittsburgh, Pa., August 1 and September 10, 1913, by I. C. Allen. 1914. 20 pp.

TECHNICAL PAPER 74. Physical and chemical properties of the petroleum of California, by I. C. Allen, W. A. Jacobs, A. S. Crossfield, and R. R. Matthews. 1914. 38 pp., 1 fig.

TECHNICAL PAPER 79. Electric lights for oil and gas wells, by H. H. Clark. 1914. 8 pp.

TECHNICAL PAPER 87. Methods of testing natural gas for gasoline content, by G. A. Burrell and G. W. Jones. 1916. 26 pp., 7 figs.

TECHNICAL PAPER 104. Analysis of natural gas and illuminating gas by fractional distillation in a vacuum at low temperatures and pressures, by G. A. Burrell, F. M. Seibert, and I. W. Robertson. 1915. 41 pp., 7 figs.

TECHNICAL PAPER 117. Quantity of gasoline necessary to produce explosive vapors in sewers, by G. A. Burrell and H. T. Boyd. 1916. 18 pp., 4 figs.

TECHNICAL PAPER 127. Hazards in handling gasoline, by G. A. Burrell. 1915. 12 pp.

TECHNICAL PAPER 130. Underground wastes in oil and gas fields and methods of prevention, by W. F. McMurray and J. O. Lewis. 1916. 28 pp., 1 pl., 8 figs.

TECHNICAL PAPER 131. The compressibility of natural gas at high pressures, by G. A. Burrell and I. W. Robertson. 1916. 11 pp., 2 figs.

TECHNICAL PAPER 161. Construction and operation of a single-tube cracking furnace for making gasoline, by C. P. Bowie. 1916. 16 pp., 10 pls.

TECHNICAL PAPER 163. Physical and chemical properties of gasolines sold throughout the United States during the calendar year 1915, by W. F. Rittman, W. A. Jacobs, and E. W. Dean. 1916. 45 pp., 4 figs.

PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS.

BULLETIN 19. Physical and chemical properties of the petroleum of the San Joaquin Valley, Cal., by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the southern California oil fields, by G. A. Burrell. 1911. 60 pp., 2 pls., 10 figs. 10 cents.

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